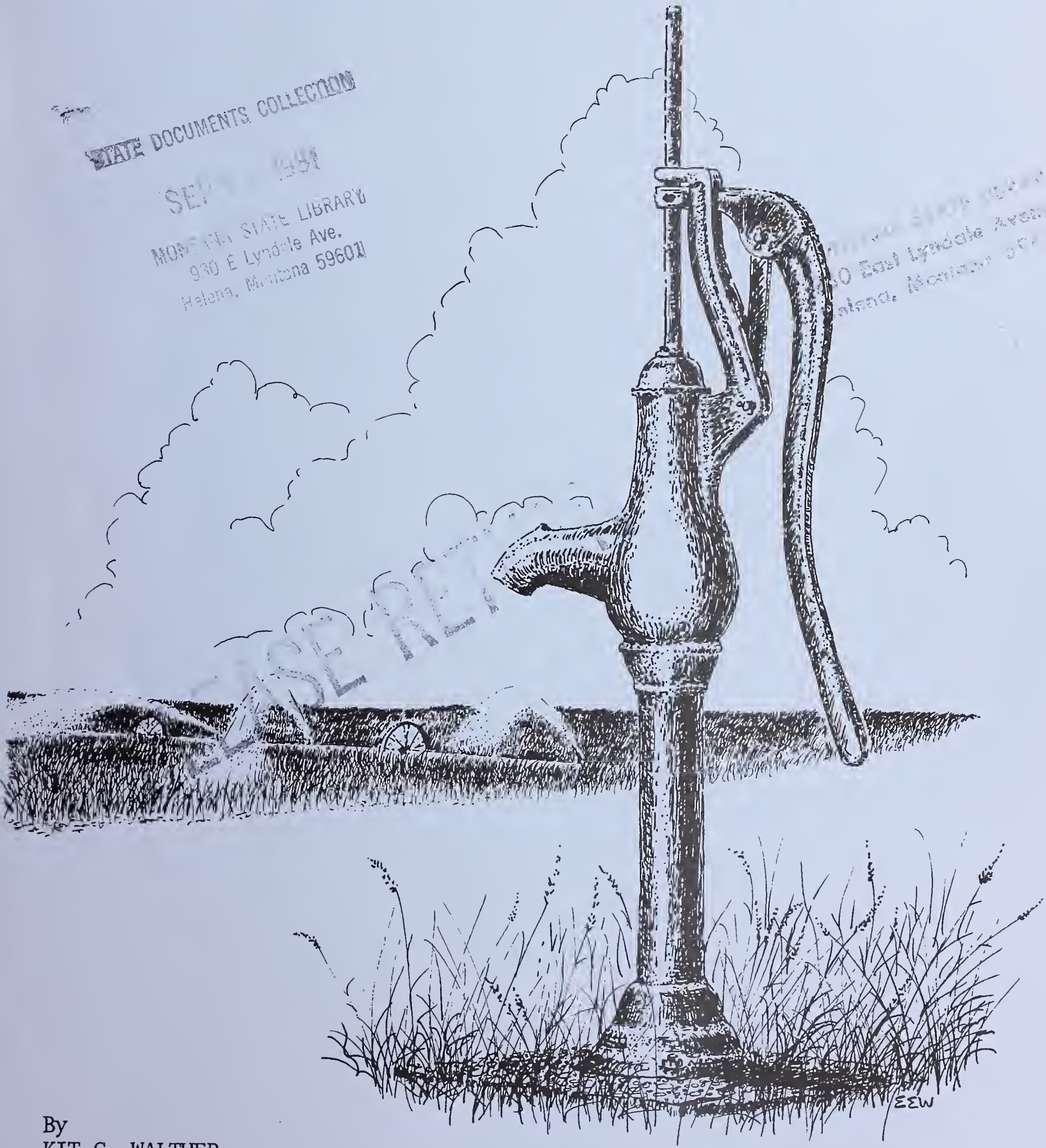
WQB Report No. 81-1

NITRATES IN WELLS OF THE GREENFIELD IRRIGATION DISTRICT FAIRFIELD, MONTANA



By
KIT C. WALTHER
WATER QUALITY BUREAU
DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES

Water Quality Bureau Report No. 81-1

Nitrates in Wells of the Greenfield Irrigation District Fairfield, Montana

prepared for

The Muddy Creek Special Water Quality Project

by

Kit C. Walther
Environmental Specialist
Water Quality Bureau
Dept. of Health & Environmental Sciences
Helena, Montana

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SUMMARY

Nitrate concentrations in groundwater of the Greenfield Bench east of Fairfield are highly variable, both in geographic distribution and in time. Concentrations exceeding the Primary Drinking Water Standards were observed in more than 25 percent of the wells sampled. Because of the unpredictable nature of groundwater nitrates on the Bench, it is advisable that well water not be given to infants less than six months of age at any time.

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Introduction

Nitrates in drinking water are a public health concern because of their association with a blood disorder in infants called methemoglobinemia. The development of methemoglobinemia from nitrate in drinking water is dependent upon the bacterial conversion of nitrate to nitrite prior to or after ingestion and is confined almost exclusively to infants less than three months of age. In some literature sources infants less than six months of age are considered susceptable to infantile methemoglobinemia.

There are several reasons why infants are susceptable to the development of methemoglobinemia, but the most important is the infant's incompletely developed capacity to secrete gastric acids which allows nitrate-reducing bacteria to reside in the upper digestive tract and convert nitrate to nitrite. Once absorbed into the blood stream, nitrite converts hemoglobin (the blood pigment responsible for transporting oxygen) to a form (methemoglobin) that is incapable of transporting oxygen. The reduced transport of oxygen to tissues results in oxygen deprivation or suffocation, which in some cases is fatal.

Serious and occasionally fatal poisonings in infants have occurred following ingestion of well waters shown to contain nitrate at concentrations exceeding 10 milligrams per liter nitrate as nitrogen (mg/lNO_3-N). The Environmental Protection Agency's Primary Drinking Water Standards establishes a maximum limit of 10 mg/lNO_3-N in public water supplies. This limit also serves as a guideline for informing persons using individual wells of potential public health problems associated with a groundwater supply.

Purpose of Nitrate Appraisal

Runoff and leachate from areas of intensive human activities are often a major source of nitrate contamination in groundwaters (i.e., manured and fertilized agricultural lands, animal feedlots, septic tanks, refuse dumps, municipal and industrial wastewaters and sludge, and urban drainage). In some cases, natural geologic deposits of nitrate also can be a source of contaminiation.

In rural areas, elevated nitrate concentrations in groundwater often are associated with intensive farming operations and fertilizer usage. Conditions conducive to nitrate leaching occur when infiltration into the ground exceeds water lost by evaporation and transpiration, where soils have high infiltration rates or low water-holding capacities, and where irrigation is practiced.

Within the Greenfield Irrigation District, conditions leading to high nitrate groundwaters were thought to exist and this short-term appraisal was initiated by the Water Quality Bureau in cooperation with the Cascade/Teton County Conservation District's Muddy Creek Special Water Quality Project. Findings from this appraisal will be used for two purposes: (1) to strengthen the Cascade/Teton County Conservation District's grant requests for federal assistance to improve irrigation practices that contribute to nitrate losses to the groundwater and contribute to high stream flows in Muddy Creek, and (2) to advise rural landowners of the nature of nitrates in the groundwater and provide recommendations for avoiding the use of high nitrate water. These recommendations are found on pages 11 and 12 of this report.

Description of the Greenfield Irrigation District

The Greenfield Irrigation District provides irrigation water to approximately 80,000 acres (90 percent of the land within the district). The majority of the irrigated lands are located on the Greenfield Bench (Fairfield Bench). Water is delivered from Pishkun Reservoir to farm units through 99 miles of main supply canals, 385 miles of laterals and 239 miles of ditches. Flood irrigation (including border ditch, border dike and wild flooding), is practiced on 90 percent of the fields, while sprinkler irrigation is practiced on only 10 percent.

The major crop grown is malting barley which in recent years has significantly increased in production. Alfalfa, hay and pasture acreages have, concurrently, declined in production. These changes in cropping patterns over the years have brought about less effective use of irrigation water. Large volumes of water are lost to the groundwater each year due to both flood irrigation practices and losses from canal and ditch seepage.

Domestic water for nearly 700 farms in the district is derived from wells. Well depths on the average range between 8 and 30 feet, but a few "deep" wells (120 feet) have been developed on the Greenfield Bench. Many of the wells are hand dug and lined with rock, culvert or concrete. Newer wells are drilled and cased with steel.

Well logs for the Greenfield Bench indicate that many wells in use today were developed in the early days of the irrigation project, in the mid 1930's. Prior to the project, many of the early homesteaders hauled their water from nearby surface waters. During the same period, a number of shallow wells were

tried but, with the exception of one, did not furnish a satisfactory amount of water. Fisher (1909) described the amount of groundwater available on the Greenfield Bench as "not . . . large, although (it) may vary locally". He further determined the source of groundwater on the Bench to be at the base of a "thin gravel veneer" (approximately 25-40 feet thick) that overlies the nonwater-bearing Colorado Shale.

In striking contrast, so abundant is the groundwater today that development of "springs" and groundwater on the Bench are being studied by the Teton Ridge Water Users Association for supplying water to ranches and farms of the water-poor Teton Ridge north and east of the Bench. The water supply system being studied is expected to service about 175 outlying users.

Thus, irrigation development on the bench has created a groundwater system that continues to be recharged by irrigation. The seasonal rise of water levels in wells is commonly recognized among the residents to follow the onset of the new irrigation season and the "turn-out" of water in canals and ditches.

Well Sites and Well-Log Descriptions

Nitrate levels were studied in thirty wells located on the first, second and third benches of the Greenfield Bench east of Fairfield (refer to Map Display and Tables 1-3 in the Appendix). Six of the 30 wells studied are "test wells" developed by the Water and Power Resources Service (WPRS). These wells are about 10 feet deep, 4 inches in diameter and cased with galvanized cutter pipe. The remaining 24 wells studied are the domestic supplies for farms. Static water levels were recorded on all WPRS wells and 6 of the 24 domestic wells. Water samples and static water level data were collected on a two week interval from May through December 1980.

All wells but one (Well Number 3) have their water source in glacial outwash materials (fan deposits) that overlie the Colorado Shale. These deposits vary in thickness over the bench, but generally are thickest near Fairfield (40 feet) and are their thinnest at the eastern edges of the bench (20-40 inches). Unfortunately, measured well depths were only available for the wells that could be accessed for measuring static water levels (a total of 12) and in only one case was it possible to match a well log report with any one of the thirty wells. Well log reports of sufficient detail to determine subsurface material were available altogether for only eleven of all well logs on the bench. These reports, however, indicated that the eleven wells extend down to the shale contact zone and appear to intercept water from the weathered (fractured) shale zone. The average depth to shale for the 11 wells is 34.8 feet (10.8 meters), but several wells were as shallow as 20 feet (6.25 meters).

Analysis of Nitrate Concentrations

Water samples for the 24 domestic wells were collected from outside spigots of houses in either 250 or 1000 ml. plastic sample bottles and preserved with 1ml or 4ml (1+1) Sulfuric Acid, respectively. Samples were stored on ice in a cooler and delivered to the Department of Health and Environmental Sciences' Chemistry Bureau for analysis. Nitrate plus nitrite concentrations were determined by the automated cadmium reduction method described in Methods for Chemical Analysis of Water and Wastes (U.S. Environmental Protection Agency, March 1979). Samples collected by WPRS also were collected, preserved and analyzed utilizing Standard Methods for the Examination of Water & Wastewater (American Public Health Association, 1975).

Nitrate-nitrogen values exceeding the EPA limit occurred in eight of the wells sampled (27 percent). Percent exceedences ranged from 100 (exceeded the limit for all samples) to 9 (exceeded the limit in 9 percent of the samples collected).

Table A. Summary of Nitrate Exceedences (%) in Greenfield Bench Wells

Well Nos.	Percent Exceedence	Nos. of Samples
12	60.0	15
15	46.6	15
16	86.6	15
22	100.0	15
S-1	27.3	11
S-2	10.0	10
S-4	9.0	11
S-5	18.0	11

Nitrate concentrations were found to range between 0.01 and 37.0 mg/l NO_3-N in 392 samples analyzed (Figures 1-4 in the Appendix). The greatest range in a single well was 35 mg/l NO_3-N recorded over a four week period. The smallest range recorded was 0.5 mg/l measured over nearly eight months. Comparisons of individual wells reveal no general trends or relationships in nitrate concentrations with precipitation patterns, irrigation scheduling, static water levels or well depths. Regression analyses applied to figures 1, 2 & 3 in the Appendix show no correlations

between static water levels and nitrate concentrations. Calculations of variance (coefficients of variation) and examination of well graphs show that nitrate concentrations vary geographically, and are even highly variable within most wells. Seventy-three percent of the wells had coefficients of variation greater than 0.20 (20 precent). The highest coefficient of variation for any well was 1.30 (130 percent). Normally, variations in nitrate concentration are small in groundwaters.

Figure 5 suggests the mean nitrate concentration in wells on the Greenfield Bench increases in the fall and reaches its peak in late October. Data, however are not adequate to substantiate if this is a seasonal trend. Mean nitrate concentrations in wells on the Greenfield Bench are significantly higher than those in Montana public water supplies using groundwater. Low concentrations of nitrates ($\leq$ 0.05 mg/l NO_3-N) occurred in only 5 percent of the samples collected from wells on the Bench, in contrast to 66 percent of the samples collected from public water supplies statewide. Table 4, page A9 gives a statistical comparison of nitrate concentrations found in public water supplies in Montana vs. the concentrations found in Greenfield Bench wells.

Factors Affecting Nitrate Dynamics

An obvious source of nitrates in the groundwater of the Greenfield Bench is the fertilizers applied to grains and pasture. But due to the variability of irrigation and fertilizer practices, soils and other factors that influence nitrate losses to groundwater, it is very difficult without site-specific studies to determine the amounts actually contributed to groundwater by fertilizers.

Olson (1980) in a two year study of the fate of tagged fertilizer nitrogen applied to irrigated corn found even at low fertilizer applications (44 lbs/ac) continued nitrogen fertilization apparently increases the total soil nitrogen pool. Regardless of the rate at which fertilizer was applied, Olson found that about three times more of it remained in the soil after two years than after one year. Repeated fertilizer applications or heavy applications of fertilizer made in the absence of tests for soil nitrogen could leave high nitrogen residues available for leaching in the soil.

Soil conditions that are conducive to nitrate leaching are common on the Bench, and it is likely that the variations observed in groundwater nitrates are also a function of the extreme variations in soil types. Sand and gravel bars for example, that extend fifty feet in width and a half mile in length, are distributed randomly over the surface of the bench. These bars have a low water-holding capacity, and when irrigated or when they receive large amounts of precipatation in conjunction with irrigation, they percolate large amounts of water to the groundwater and possibly contribute "slugs" of fertilizer nitrogen because of their coarse nature and leachability. Soil depth too, may also affect nitrate leaching. In areas of deeper heavier soils and lower permiabilities, deep leaching of nitrates would be less detectable than in areas of shallow lighter soils over gravels. Because soil depths and textures are so variable it is likely that there are areas that contribute more nitrates than others, causing groundwater "hot spots".

Nitrate losses in localized areas also may be influenced by a caliche layer that covers 5-10 percent of the Bench area, mostly on the first and second benches. This layer is formed from cemented gravels and fines, and forms an impervious -- or partially impervious -- layer at depths of

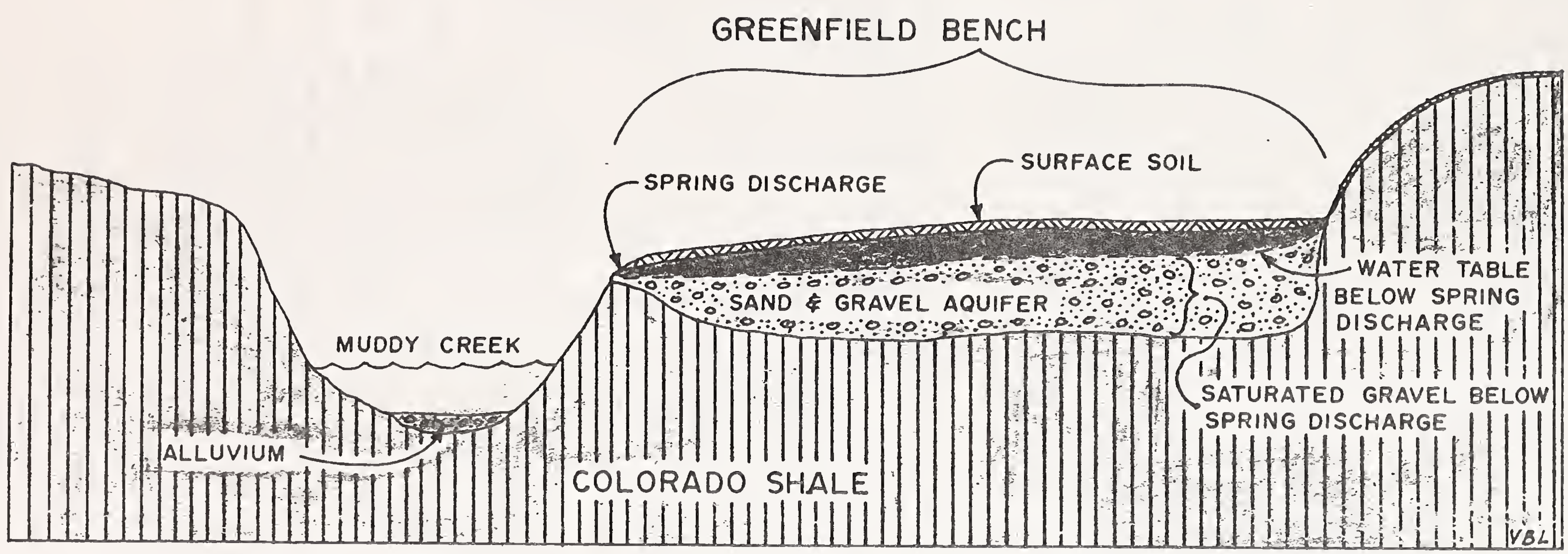

Figure A.

GEOLOGIC

CROSS SECTION

MUDDY CREEK — GREENFIELD BENCH

10-30 inches. In certain areas the layer is within only a few inches of the soil surface and, in some cases, it has been mechanically broken as a result of land leveling. The caliche layer often is found on the bench in association with sandy loam and gravely loam soils. The very shallow soils over the caliche quite possibly could be sites of high nitrate leaching due to the shallow rooting depths and subsurface irrigation water traveling horizontally on top of the impervious layer. "Slugs" of nitrates could possibly reach the groundwater when irrigation waters reach a "window" in the discontinuous caliche and move vertically to the shallow groundwater. Because these caliche layers are localized they too might account for some of the variabilities in nitrate levels in wells.

A possible second source of nitrates in wells on the Greenfield Bench is the marine Colorado Shale that underlies the terrace deposits (Figure A, Page 9). Power (undated) studied the chemical forms and transformations of inorganic nitrogen in shale beds in the Tongue River and Sentinel Butte formations. Analyses of sedimentary rocks collected in 30 centimeter depth increments revealed that below 10 meters, shale contains 10 to 40 ppm[1/] exchangeable ammonium (NH_4^+) nitrogen and only 1-3 ppm of NO_3-N. However, from 2 to 10 meter depths the maximum NO_3-N concentrations were 20 to 40 ppm and the exchangeable NH_4 nitrogen only 2 to 5 ppm. Small quantities of free water in the lower part of shallow lignite beds (resting on shales 6 meters deep) often had a (natural) nitrate nitrogen content in the water of 20 to 150 ppm. Nitrification in the Paleocene shales (transformation of exchangeable ammonium to nitrates) was implied to have occurred at depths up to 10 meters

1/ ppm - parts per million. Nitrate-nitrogen values were expressed in Power's paper in ppm. At these low concentrations ppm are equivalent to mg/l.

(32 feet). Other researchers have presented similar data on watersoluble, exchangeable, and fixed NH_4 in modern marine sediments from the Netherlands. Power indicated he has observed similar findings while investigating marine shales in Alberta, Canada (pers. comm.).

Whether the shales underlying the Greenfield Bench contribute nitrates to the groundwater cannot be determiend without further study. The possibility for nitrification to occur seems to be present considering the shallow character of the shale. If wells actually remove water from the fractured shale of the shale/soil contact zone, it seems likely that shale-derived nitrates could be present in the wells.

Public Health Recommendations

Nitrate removal requires sophisticated treatment systems that are too expensive for practical consideration. But because the 10 mg/l nitrate-nitrogen limit is established to prevent acute illness in infants, there are several practical measures that can be used to reduce infant exposure.

(1) Waters that have 10 mg/l NO_3-N or more should not be given to infants. To be safe, infants should not be given any water that is obtained from wells on the Greenfield Bench, even if it has been tested and shown to have safe levels of NO_3-N. Nitrate concentrations in the Greenfield Bench wells are very unpredictable over time and consumption of high nitrate water by infants for a period as short as a day has been found to result in the occurance of infantile methemoglobinemia.

(2) Infants should be breast-fed or fed bottled water that is free of nitrates or formulas that are either ready-to-feed or prepared with nitrate-free bottled water.

(3) Boiling the water will not remove nitrates, in fact, it can concentrate nitrates by as much as 40 percent.

(4) For safety reasons, the above recommendations should apply not only to infants less than 3 months of age, but also to those up to 6 months of age.

(5) Physicians and local health departments should become aware of the nitrate problems on the Greenfield Bench and inform the residents of the area accordingly.

(6) Healthy adults are reported to be able to consume large quantities of nitrates in drinking water with little, if any, effect. The National Academy of Sciences also has found no scientific evidence that links nitrate concentrations in water with carcinogenic (cancer causing) potential (Craun, 1980).

Recommendations for Future Study

The seemingly unpredictable nature of nitrates in groundwater on the Greenfield Bench merits future examination.

(1) More domestic wells sampled on a biweekly basis for a full water year should be included in a broader-based reconnaisance study.

(2) An interdisciplinary study should be designed to quantify the influences that fertilizer and irrigation practices, soils distribution, precipitation patterns and geochemistry of the Colorado Shale have on nitrate dynamics in the groundwater of the Greenfield Bench and make appropriate recommendations for their reduction.

Pesticides in Groundwater

As an excursion from the nitrate reconnaisance, pesticides (Endrin, Toxephene and 2,4-D) were analyzed on two occasions. Samples were collected from 24 domestic wells and one domestic surface water. All parameters were found to be below the detection limits of the analytical procedure.

Acknowledgements

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6. U.S. EPA 1979. Methods for Chemical Analysis of Water and Wastewater. EPA-600/4-79-020. U.S. Environmental Protection Agency, Cincinnati, Ohio.

7. WPRS 1980, Statement of Work: Nutrients in Open Drains. Water and Power Resources Service. Billings, Montana.

APPENDIX

TABLE 1. Key to Well Ownerships

Well Nos.	Owner
1.	Oscar Kjellgren
2.	Lawrence Beerman
3.	Earl Mills
4.	Dean Hinkley
6.	Chester Ostberg
7.	Ray Foreman
8.	Mr. Van Setton
9.	Roy Konen
10.	Frank Fleming
11.	Royal Hawthorne
12.	R. Van Bolcum
13.	John Winter
14.	Harold Klinker
15.	Ron Ostberg
16.	Norm Klinker
17.	Howard Riphenburg
18.	Alvin Schmidt
19.	Richard Jergenson
20.	Arnold Gettel
21.	Jack Knight
22.	Paul Brunner
23.	Dale Norheim
24.	Charles Humphry
25.	Gerold Mangold
S-1 through S-6	Water and Power Resource Service

*NOTE - Well No. 5 was purposely omitted because it is actually a surface source for domestic water taken from an irrigation drain.

FIG.1 NITRATE CONCENTRATIONS and STATIC WATER LEVELS IN INDIVIDUAL WELLS

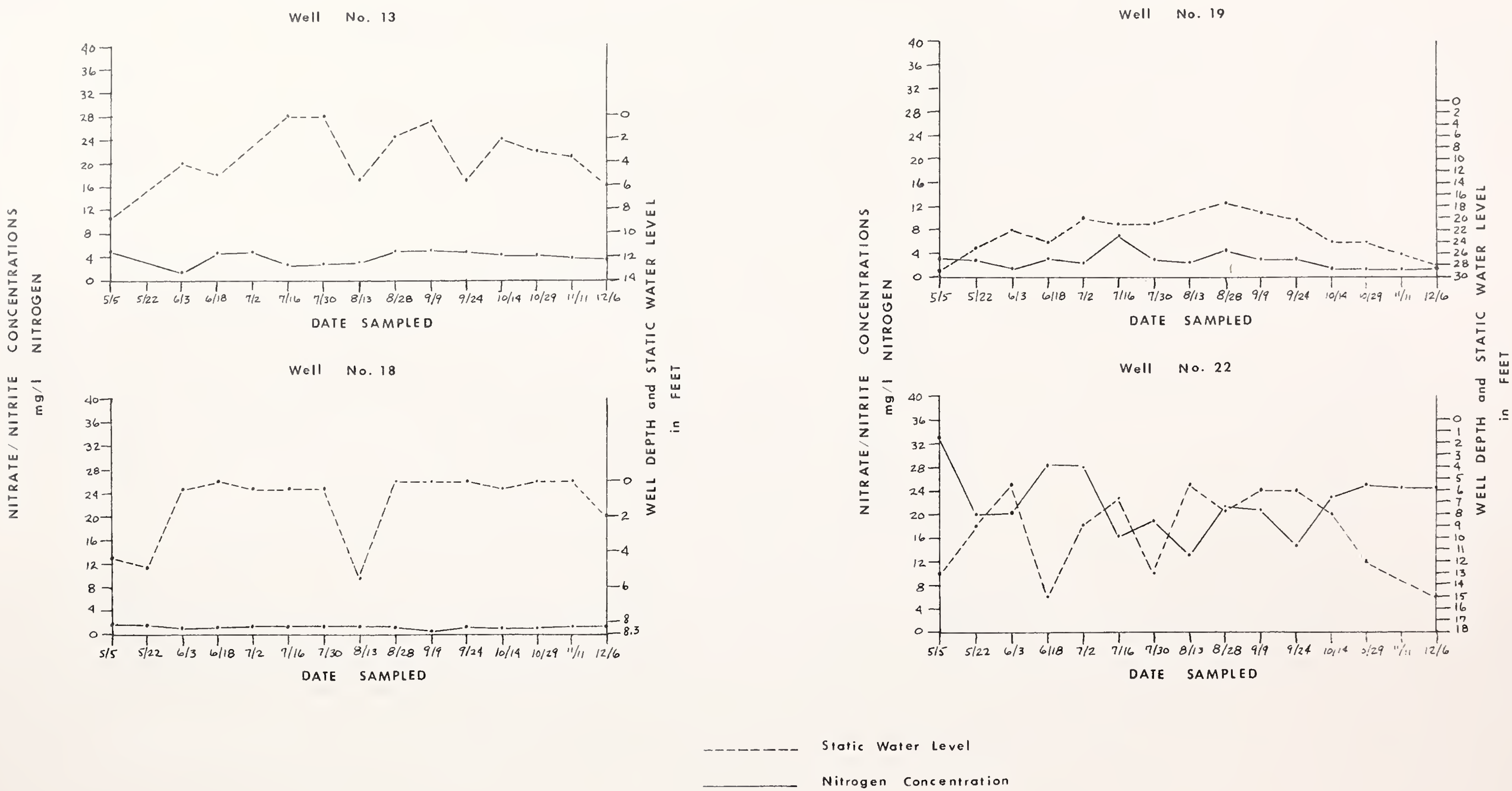

FIG. 2 NITRATE CONCENTRATIONS and STATIC WATER LEVELS IN INDIVIDUAL WELLS

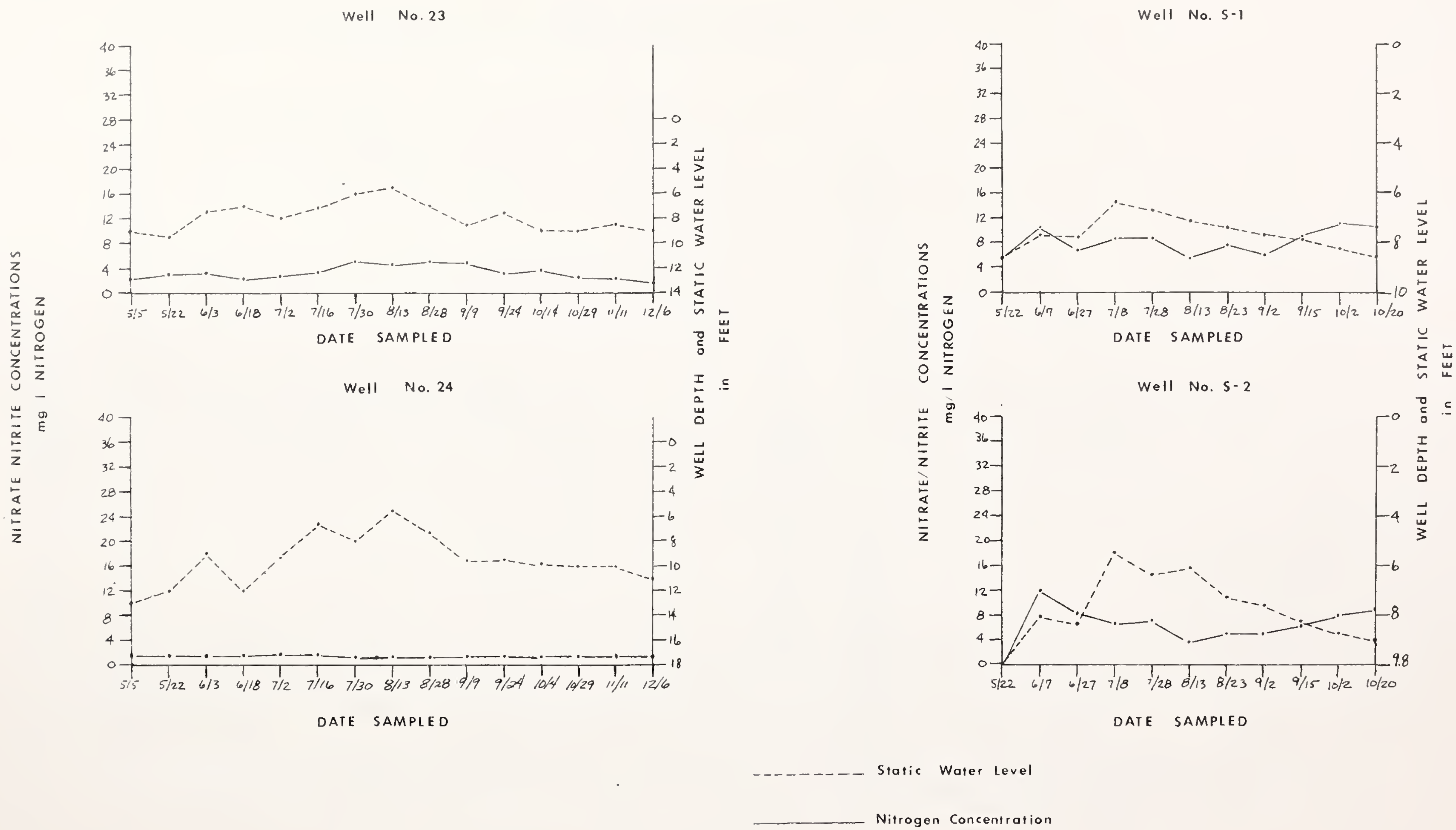

FIG. 3 NITRATE CONCENTRATIONS and STATIC WATER LEVELS IN INDIVIDUAL WELLS

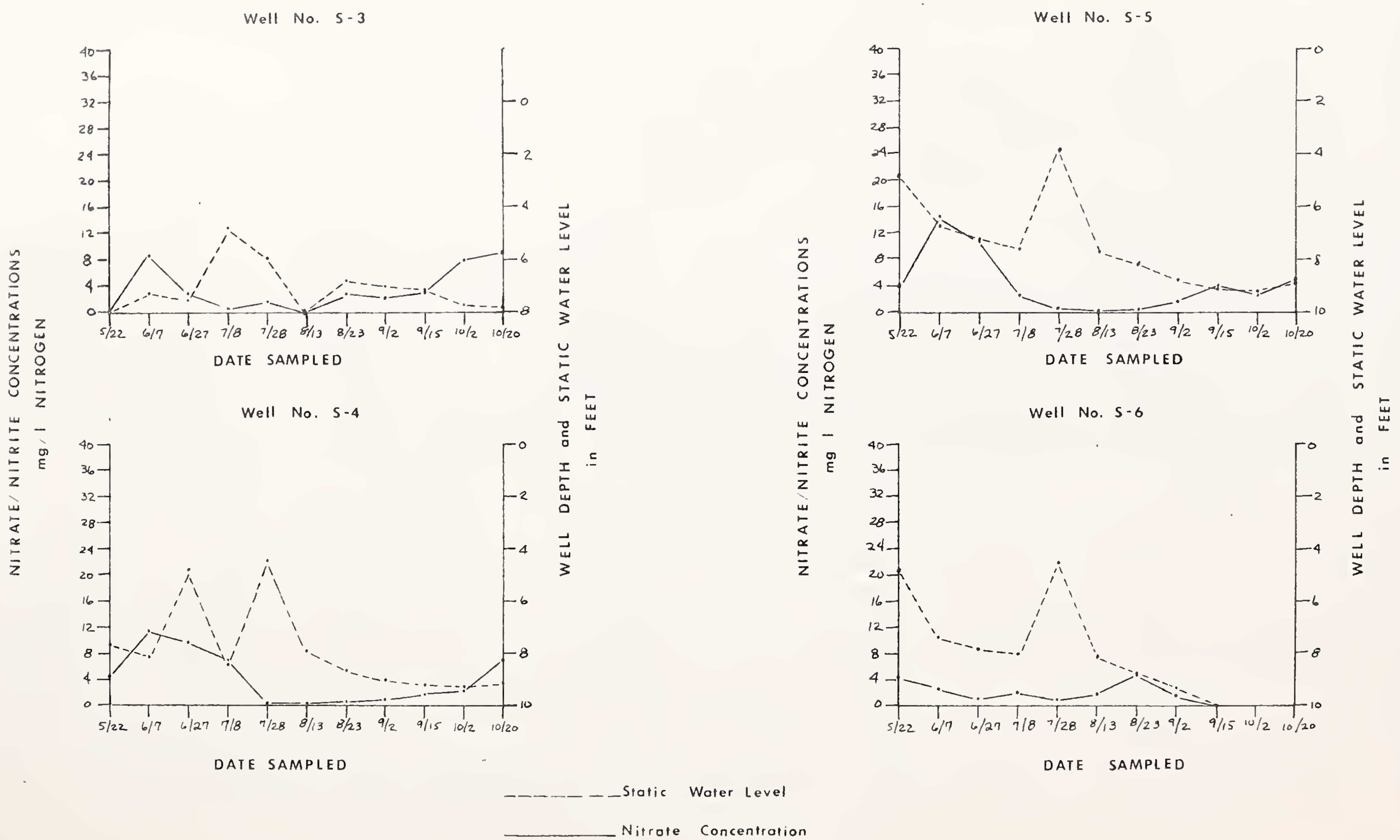

FIG. 4 NITRATE CONCENTRATIONS IN INDIVIDUAL WELLS

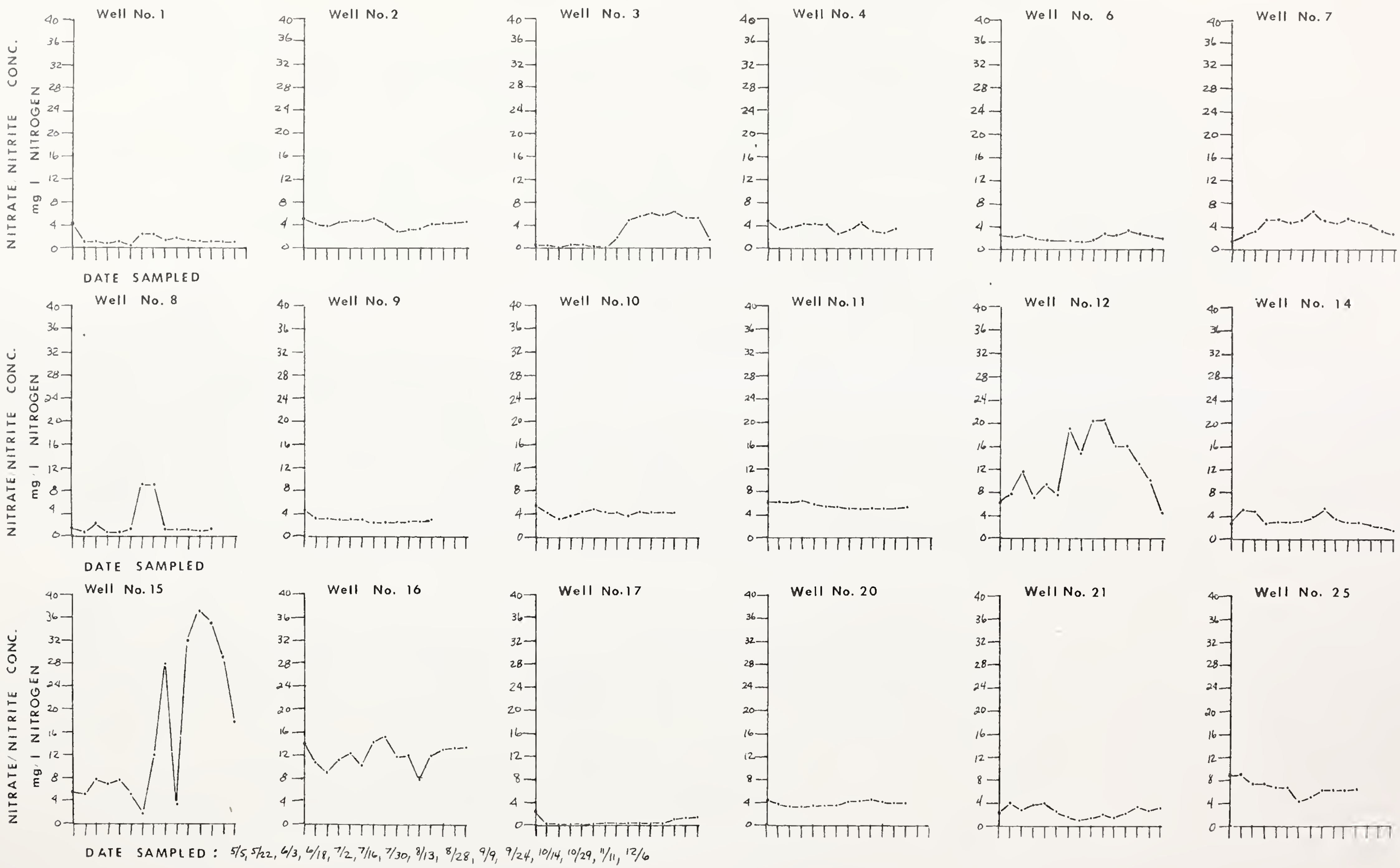

FIG. 5 MEAN NITRATE CONCENTRATIONS OF 24 AGGREGATED DOMESTIC WELLS

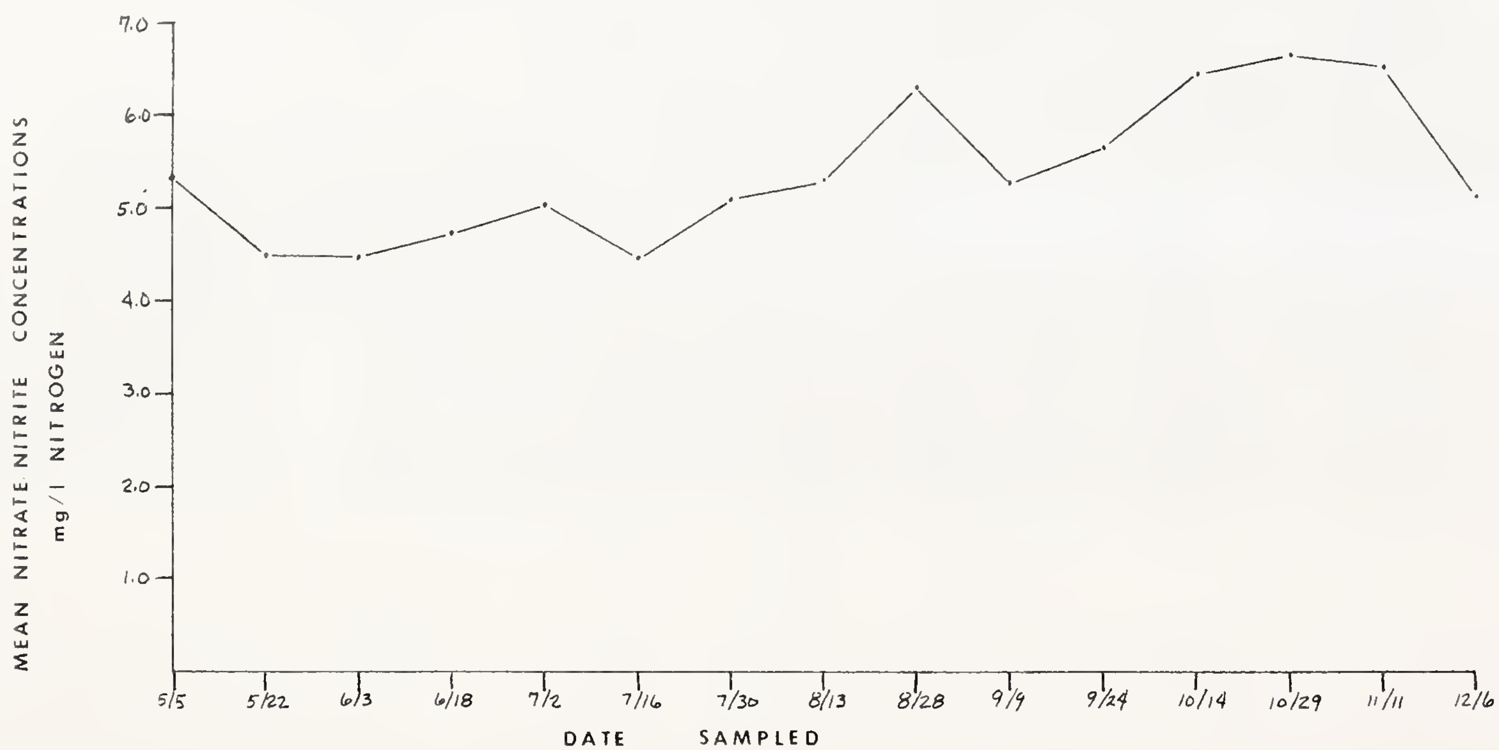

TABLE 2

GREENFIELD IRRIGATION DISTRICT-WELL ANALYSES

SAMPLE NOS.

DATE 1980	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
WELL DEPTH IN FEET	18	32	120	35	SW	16	16				20	20	14	UNK		20	20	20	30		21	18	14	18	25
NITRATE + NITRITE CONCENTRATION mg/l ASN																									
5/5	4.10	4.50	0.40	4.80	1.40	2.7	1.8	1.60	4.4	5.60	6.20	6.20	4.60	2.70	5.40	14.0	2.40	1.90	3.20	4.10	2.3	33.0	2.20	1.50	8.80
5/22	1.0	4.1	0.33	3.60	1.25	2.3	2.45	0.65	3.5	4.20	6.2	7.8	NS	5.4	5.0	10.8	0.45	1.80	2.95	3.80	4.0	20.0	3.15	1.50	9.0
6/3	1.14	3.95	0.01	3.95	1.66	2.35	3.4	2.20	3.45	3.55	6.10	11.8	1.6	4.8	7.9	9.2	0.23	1.24	1.75	3.45	2.9	20.5	3.4	1.56	7.4
6/18	0.74	4.35	0.45	4.25	1.34	1.85	5.3	0.45	3.45	3.95	6.40	7.20	---	2.90	6.90	11.4	0.20	1.44	3.45	3.45	3.8	28.5	2.35	1.6	7.5
7/2	1.0	4.8	0.18	4.3	1.60	1.80	5.6	0.47	3.20	4.4	5.9	9.5	4.9	3.0	7.7	12.4	0.17	1.60	2.3	3.5	4.0	28.0	2.7	1.9	6.9
7/16	0.25	4.8	.01	4.20	2.5	NS	4.8	1.20	3.10	5.0	5.4	7.8	2.7	3.1	5.1	10.2	0.32	1.70	7.3	3.7	2.5	16.50	3.5	1.9	6.9
7/30	2.2	5.3	2.0	2.5	1.1	1.6	5.3	9.3	2.6	4.3	5.6	19.0	2.7	3.2	1.9	14.4	0.61	1.7	3.1	3.8	1.5	19.0	5.2	1.6	4.2
8/13	2.2	4.2	5.1	3.6	1.3	1.4	6.6	9.2	2.6	4.4	5.1	14.8	3.3	4.0	12.0	15.2	0.48	1.7	2.4	4.1	1.0	13.4	4.5	1.4	5.4
8/28	1.5	3.3	5.8	4.5	1.9	1.7	5.2	1.1	2.7	3.9	5.2	20.5	4.9	5.6	28.0	11.8	0.44	1.5	4.2	4.2	1.5	21.5	5.0	1.5	6.2
9/9	1.9	3.5	6.1	3.3	2.2	2.9	4.5	1.1	2.7	4.4	5.3	23.0	5.0	3.7	3.4	12.0	0.62	0.31	3.1	4.5	2.0	20.5	4.7	1.7	6.2
9/24	1.5	3.6	5.9	2.7	2.0	2.4	5.6	1.2	2.9	4.2	5.0	16.0	4.7	2.7	32	7.8	0.74	1.50	3.3	4.1	1.6	14.5	3.1	1.6	6.3
10/14	1.3	4.2	6.2	3.8	2.6	3.8	4.8	0.9	3.3	4.2	5.3	16.0	4.1	2.6	37	12	0.7	1.3	1.6	4.0	2.2	23.0	3.9	1.7	6.5
10/29	1.4	4.3	5.6	NS	2.6	2.8	4.1	1.5	NS	4.3	5.5	13.0	4.1	2.2	35	13.0	1.3	1.3	1.5	4.0	3.4	25	2.3	1.8	8.8
11/11	1.38	4.4	5.8	NS	3.0	2.2	3.6	NS	NS	NS	NS	10.5	3.75	2.0	29	13.4	1.5	1.38	1.55	NS	2.8	24.5	2.15	1.84	NS
12/6	1.37	4.71	1.7	NS	3.29	1.88	2.85	NS	NS	NS	NS	4.69	3.45	1.54	17.9	13.6	1.59	1.43	1.51	NS	3.25	24.5	1.85	1.77	NS
n	15	15	15	12		14	15	13	12	13	13	15	13	15	15	15	15	15	15	13	15	15	15	15	13
x	1.53	4.27	3.04	3.79		2.26	4.39	2.37	3.16	4.34	5.63	12.52	3.83	3.30	15.61	12.08	0.78	1.45	2.88	3.9	2.58	22.15	3.33	1.66	6.93
c	0.57	0.13	0.90	0.18		0.28	0.30	1.30	0.16	0.12	.08	0.44	0.27	0.36	0.82	0.17	0.82	0.26	0.52	.08	0.38	0.24	0.33	.09	0.20
mn	0.25	3.3	0.01	2.5		1.4	4.8	0.45	2.6	3.55	5.0	4.69	1.6	1.54	1.9	7.8	0.17	0.31	1.50	3.45	1.0	13.4	1.85	1.4	.42
mx	4.10	4.8	6.1	4.8		3.8	1.8	9.3	4.4	5.6	6.4	23.0	5.0	5.6	37.0	15.2	2.4	1.9	7.3	4.5	4.0	33	5.2	1.9	9.0
r	3.85	1.5	6.19	2.3		2.4	6.6	8.85	1.8	2.05	1.4	18.31	3.4	4.06	35.1	7.4	2.37	1.59	5.8	1.05	3.0	19.6	3.35	0.5	4.8

TABLE 3

GREENFIELD IRRIGATION DISTRICT
WELL ANALYSES BY WAPRS

SAMPLE NOS

	S-1	S-2	S-3	S-4	S-5	S-6
APPROX. WELL DEPTH IN FT.						
	10.0	9.8	8.16	10.0	10.0	10.0
NITRATE/NITROGEN CONCENTRATION mg/l						
5-22	5.7			4.3	4.0	4.3
6-7	10.5	12.0	8.5	11.5	14.5	2.5
6-27	6.8	8.2	2.8	9.8	10.8	1.2
7-8	8.5	6.5	0.5	7.0	2.5	2.0
7-28	8.8	7.2	1.8	0.3	0.5	0.9
8-13	5.8	3.8		0.3	< 0.1	1.8
8-23	7.8	5.2	2.8	0.6	0.3	4.4
9-2	6.0	5.2	2.2	1.1	1.8	1.6
9-15	9.2	6.2	3.4	1.9	4.0	
10-2	11.5	8.0	8.0	2.2	2.5	
10-20	10.5	8.8	9.2	7.0	5.0	
n	11	10	9	11	11	8
$\bar{x}$	8.28	7.11	4.36	4.18	4.17	2.34
s	2.04	2.31	3.27	4.03	4.56	1.33
C	0.25	0.33	0.75	0.96	1.09	0.57
r	5.8	8.2	8.7	11.2	14.49	3.5
mn	5.7	3.8	0.5	0.3	< .01	0.9
mx	11.5	12.0	9.2	11.5	14.5	4.4

TABLE 4

Statistical Comparison of Nitrates from Wells of the Greenfield Irrigation District vs. Public Water Supplies, Statewide

	Public Water Supplies	Greenfield District
Mean	1.36 mg/l NO_3-N	5.42 mg/l NO_3-N
Median	0.30 mg/l NO_3-N	3.79 mg/l NO_3-N
Minimum	$\leq$ 0.01 mg/l NO_3-N	$\leq$ 0.01 mg/l NO_3-N
Maximum	34.00 mg/l NO_3-N	37.0 mg/l NO_3-N
Range	33.99 mg/l NO_3-N	36.99 mg/l NO_3-N
Standard Deviation	3.359	5.85
Total Number of Samples	1167	392

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
FAIRFIELD QUADRANGLE
MONTANA
15 MINUTE SERIES (TOPOGRAPHIC)
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
VAUGHN QUADRANGLE
MONTANA
15 MINUTE SERIES (TOPOGRAPHIC)
Nitrate/Nitrite Concentrations
mg/l Nitrogen
X̄ = mean Conc.
Mn = minimum Conc.
Mx = maximum Conc.
C = coefficient of verience
6 well no.
25 well depth
GREENFIELD BENCH
THIRD BENCH
SECOND BENCH
FIRST BENCH
ASHUELOT BENCH
Third Bench
Second Bench
First Bench
Fairfield
Power
Vaughn
TETON CO
CASCADE CO

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